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IS 14205-1 (1994): Steam Turbine, Part 1: Specification
[ETD 15: Rotating Machinery]



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“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक
भाप टरबाइन
भाग 1 विशिष्टि

Indian Standard

STEAM TURBINE

PART 1 SPECIFICATION

UDC 621 : 165

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 45-1 (1991), issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of the Rotating Machinery Sectional Committee (ET 15) and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as Indian Standard without deviations.

CROSS REFERENCES

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 651 : 1979	IS 9779 : 1981 Sound level meters	Technically equivalent
IEC 953-1 : 1990	14198 (Part 1) : 1994 Rules for steam turbine thermal acceptance tests : Part 1 Method A — High accuracy for large condensing steam turbines	Identical

(Continued on third cover)

Indian Standard

STEAM TURBINE

PART 1 SPECIFICATION

1 Scope and object

This part of International Standard IEC 45 is applicable primarily to steam turbines driving generators for electrical power services. Some of its provisions are relevant to turbines for other applications.

The purpose of this part is to make an intending purchaser aware of options and alternatives which he may wish to consider, and to enable him to state his technical requirements clearly to potential suppliers.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 651: 1979, *Sound level meters*.

IEC 953-1: 1990, *Rules for steam turbine thermal acceptance tests - Part 1: Method A*.

IEC 953-2: 1990, *Rules for steam turbine thermal acceptance tests - Part 2: Method B*.

ISO 2372: 1974, *Mechanical vibration of machines with operating speeds from 10 to 200 rev/s. Basis for specifying evaluation standards*.

ISO 7919-1: 1986, *Mechanical vibration of non-reciprocating machines - Measurements on rotating shafts and evaluation - Part 1: General guidelines*.

3 Terms and definitions

For the purposes of this part, the following terms and definitions apply:

3.1 Turbine type

superheat turbine: A turbine whose initial steam is significantly superheated.

wet-steam turbine: A turbine whose initial steam is saturated or nearly so. (Also referred to as saturated-steam turbine.)

reheat turbine: A turbine from which the steam is extracted part-way through the expansion, reheated (one or more times) and readmitted to the turbine.

non-reheat turbine: A turbine in which the steam is not reheated.

mixed-pressure turbine: A turbine provided with separate inlets for steam supplied at two or more pressures.

back-pressure turbine: A turbine whose exhaust heat will be used to provide process heat, and whose exhaust is not directly connected to a condenser. The exhaust pressure will normally be above atmospheric pressure. (Also referred to as a non-condensing turbine.)

condensing turbine: A turbine whose exhaust is directly connected to a condenser. The exhaust pressure will normally be below atmospheric pressure.

regenerative-cycle turbine: A turbine from which some of the steam is extracted part-way through the expansion in order to heat feed water.

extraction turbine: A turbine in which some of the steam is extracted part-way through the expansion in order to provide process steam. If the turbine includes means for controlling the pressure of the extracted steam, it is called a controlled (or automatic) extraction turbine.

combined cycle: A combination of boiler, steam turbine and gas turbine, in which the gas turbine exhaust normally contributes to the heat input to the steam cycle.

single-line combined-cycle: A combined-cycle plant in which the steam turbine and gas turbine both drive the same generator. It is not possible to segregate the separate outputs of the steam turbine and the gas turbine; and definitions, such as those of heat rate or output given later in this standard, no longer apply.

NOTE - The terms in 3.1 may be combined to define the features of any particular unit.

3.2 *Methods of initial steam admission*

full-arc: All of the governing (control) valves supply steam uniformly to the admission inlet belt of the first stage.

partial-arc: The inlet belt to the first stage is divided into discrete arcs of admission, steam being supplied separately to each arc through, normally, one governing valve; governing valves operate wholly or partially in sequence.

3.3 *Conditions*

terminal conditions: The terminal conditions for a steam turbine or turbine-generator are the conditions imposed on the plant at their terminating points of the contract. These may typically comprise:

- initial and hot reheat steam conditions;
- cold reheat pressure;
- final feed water temperature;
- exhaust pressure;
- power output;
- speed;
- extraction requirements.

specified or rated terminal conditions: The conditions at the terminating points of the turbine or turbine-generator contract, with which specified output and/or heat rate shall be stated and/or guaranteed. Note that some nuclear steam generators supply steam at a pressure which increases as load reduces, and the turbine design must allow for this.

steam conditions: The conditions which define the thermodynamic state of steam, normally (static) pressure and temperature or dryness fraction (or quality). Steam pressure should always be quoted in absolute units, not as gauge pressure.

Initial steam conditions: The steam conditions at inlet to the main stop valves.

maximum steam conditions: The highest steam conditions at which the turbine is required to operate continuously.

NOTE - The highest steam conditions should not exceed those permitted by 6.2 a) and 6.2 b).

Induction steam conditions: The steam conditions of any additional steam entering the turbine at any pressure lower than the initial pressure.

dual steam conditions: The combination of initial and induction steam conditions appropriate to a mixed-pressure turbine.

reheat steam conditions: The steam conditions at the inlet to the reheat stop valves. (Also referred to as hot reheat steam conditions.)

cold reheat steam conditions: The steam conditions at the outlet of the turbine preceding the reheater.

extraction steam conditions: The steam conditions at the extraction connections of the turbine, of steam extracted for feed-heating or process purposes.

exhaust conditions: The steam conditions at the exhaust connection from the turbine.

NOTE - Use of the word "design" in respect of any steam conditions, power output, speed, etc., should be avoided in the contract documents. This terminology should only be applied to the values used in design calculations such as the design pressure for a pressure vessel.

3.4 *Speeds*

rated speed: The speed at which the turbine is specified to operate at its rated output.

maximum continuous speed: The upper limit of the operating speed of the turbine for continuous service.

overspeed trip setting: The speed at which the overspeed trip is set to operate.

temporary speed rise: The transient increase in turbine speed following a load rejection, with the speed governing system in operation. The rated temporary speed rise applies if the rated output is rejected at the rated speed.

maximum transient speed: Maximum rotational speed following rejection of maximum capability by disconnecting the generator from the electric system (with auxiliary supplies previously disconnected) and the speed governing (control) system in operation.

permanent speed rise: The final steady-state increase in turbine speed following a load rejection, with normal governor control.

maximum speed rise: The transient increase in turbine speed following a load rejection, with the speed governing system inoperative and the overspeed trip operative. The rated maximum speed rise applies if the rated output is rejected at rated speed.

3.5 Powers

NOTE - All these powers or outputs refer to operation of the turbine at rated terminal conditions (except where stated otherwise).

power: The power supplied by the turbine or its driven machine. The definition should state the position of measurement and any deductions for losses or auxiliary power. (Also referred to as output or load.)

net power at coupling: The power at the turbine coupling, less the power supplied to turbine auxiliaries if driven separately.

generator output: Power at the generator terminals, after the deduction of any external excitation power.

maximum continuous rating (MCR) (electrical generating set): The power output assigned to the turbine-generator by the supplier, at which the unit may be operated for an unlimited time, not exceeding the specified life, at the specified terminal conditions. This is the rating which will normally carry a guarantee of heat rate. The governing (control) valves will not necessarily be fully open. (Also referred to as rated output, rated power, or rated load.)

maximum continuous rating (MCR) (other than electrical generator drives): The power output assigned to the turbine by the supplier, at which the unit may be operated for an unlimited time, not exceeding the specified life, at the specified terminal conditions. This is the rating which will normally carry a guarantee of heat rate. The governing (control) valves will not necessarily be fully open. The power shall be that delivered at the turbine coupling, or the coupling of the driven machine, as may be agreed. (Also referred to as rated output, rated power, or rated load.)

maximum capability: The power output that the turbine can produce with the governing (control) valves fully open and at the specified terminal conditions. (Also referred to as valves-wide-open capability.)

maximum overload capability: The maximum power output that the unit can produce with the governing (control) valves fully open, and with the terminal conditions specified for overload, e.g. with final feed water heater bypassed, or with increased initial steam pressure.

most economical continuous rating (ECR): The output at which the minimum heat rate or steam rate is achieved at the specified terminal conditions.

net electrical power: The generator output (with external excitation power deducted) minus the electrical auxiliary power.

electrical auxiliary power: Power taken by turbine and generator auxiliaries not driven by the turbine. This will normally include all power used for control, lubrication, generator cooling and sealing. It may also include additional auxiliaries such as motor-driven boiler feed pumps. The purchaser and contractor should agree on which additional auxiliaries should be included.

3.6 *Steam flow rate and steam rate*

Initial steam flow rate: The flow rate of steam at initial conditions to the turbine, including any steam supplied to valve stems, glands, or balance pistons, and any steam supplied to auxiliary plant such as boiler feed pump turbines, steam/steam reheaters, ejectors, etc.

steam rate: The ratio of initial steam flow rate to power output.

3.7 *Heat rates*

(See also IEC 953, where the definitions are given in greater detail)

heat rate: The ratio of external heat input to the cycle to power output. It is the reciprocal of thermal efficiency.

guarantee heat rate: The heat rate upon which the guarantee or offer is based for a stated output with the rated terminal conditions, and for the cycle described in 19.1. Any assumption with regard to extraneous flows, make-up, heat addition or removal, shall be stated. In all cases, the formula used to define the heat rate shall be stated in the contract.

uncorrected test heat rate: The heat rate obtained by inserting test results in the formula stated in the contract.

fully-corrected heat rate: The heat rate which would have been achieved during the test if the terminal conditions had been as specified, and all ancillary plant outside the supplier's responsibility had performed exactly in accordance with its guarantee.

3.8 *Efficiency*

thermal efficiency: The reciprocal of heat rate, and therefore defined as the ratio of power output to external heat input to the cycle. If guaranteed, the definition of thermal efficiency shall be stated in the contract.

3.9 *Operational regimes (modes)*

base-load operation: Operation at maximum continuous rating (MCR) or a high fraction of this throughout a prolonged period.

two-shift operation: Operation at MCR or a high fraction of this for about 16 h or less out of 24 h per day, the remaining time being shut down.

one-shift operation: Operation at MCR or a high fraction of this for about 8 h out of 24 h per day, the remaining time being shut down.

load cycling: Operation alternating between high and low levels of load on a regular basis.

peak-load operation: Operation at high load for short periods, typically 1 h to 3 h, at times of peak demand. The number of peaks per day is not implied. The remaining time is spent shut down.

NOTE - Although the above definitions are of a general nature, they may be made more specific by stating whether the turbine is or is not subject to periodic shutdown, which might typically be categorized as a 36 h shutdown or a 48 h shutdown.

3.10 *Methods of load variation*

constant-pressure operation: Operation in which the initial steam pressure is maintained sensibly constant, and where load is reduced by gradually closing the governing (control) valves either in parallel (full-arc admission) or in sequence (partial-arc admission).

sliding-pressure operation: Operation in which load is changed by variation of the initial steam pressure; the governing (control) valves, which operate in parallel, all remaining at their fully-open position.

modified sliding-pressure: Operation in which load changes in the range from 100 % to about 90 % of rated output are achieved by operating all the governing (control) valves in parallel, the initial steam pressure remaining constant; below about 90 % of rated output changes of load are, where practicable, achieved by variations of the initial steam pressure, while the governing (control) valves remain near the position corresponding to 90 % of rated output.

hybrid operation: Operation of a partial-arc admission machine in which load is reduced by sequential closing of the governing (control) valves to a value corresponding to the minimum allowable number of governing (control) valves remaining fully open, the initial steam pressure remaining constant; further reduction of load is achieved by reduction in initial steam pressure while those governing (control) valves are open remain at or near their fully-open position.

throttle governing: The governing (control) valves operate in parallel, or nearly so, this being the normal control mode of a full-arc admission turbine in constant-pressure operation.

nozzle governing: The governing (control) valves close in sequence, this being the normal control mode of a partial-arc admission turbine in constant-pressure operation.

3.11 *Operational life*

calendar age: The total elapsed life of the plant, expressed in months or years, measured from first synchronization.

running hours: The number of hours during which the machine has been on load.

3.12 *Control and protection*

governing system: The combination of devices and mechanisms which convert control signals into valve positions in a characteristic manner. This includes the speed governor, the speed control mechanism, the speeder device (speed changer), the unloading systems and any steam valve operating devices.

turbine-generator protection system: The overall system provided to protect the turbine-generator from faults within itself or elsewhere in the electrical transmission system.

steady-state condition: A condition which has constant mean values of speed and load with limited random deviations.

stable operation: A system is said to be stable if it achieves a steady-state condition following a speed or load disturbance.

steady-state regulation (speed governing droop): Steady-state speed change expressed as a percentage of rated speed, when the load of an isolated unit is changed between rated load and zero load, with identical setting of the speed governing (control) system, assuming zero dead band.

steady-state incremental speed regulation (incremental speed droop): The rate of change of the steady-state speed with respect to load at a given steady-state speed and load, assuming zero dead band. The value is the slope of the tangent to the steady-state speed/load curve at the load under consideration.

dead band of the speed governing (control) system: The total magnitude of the change in steady-state speed (expressed as a percentage of rated speed) within which there is no resultant change in the position of the governing (control) valves. The dead band is a measure of the sensitivity of the system.

maximum load inaccuracy or non-linearity: The maximum deviation in load, expressed as a percentage of rated load, of the load-speed curve from the straight line corresponding to the overall speed droop, when operating under defined conditions of control equipment environment (e.g. temperature, humidity) and power supply (e.g. voltage, oil pressure).

governor environmental stability: The change in load, expressed as a percentage of rated load, resulting from a given change of any independent variable other than set point or speed. Such variables are lapsed time, temperature, vibration, barometric pressure, supply voltage and frequency.

short-term stability: The change in demanded load, expressed as a percentage of rated load, for any fixed set point and speed over any period of 30 min for which the ambient conditions are within the defined envelope.

long-term stability: The change in average demanded load, expressed as a percentage of rated load, for fixed set point and speed between two periods of 30 min at an interval of 12 months. For both test periods the ambient conditions should be within the required envelope, but may not necessarily be closely similar.

4 Guarantees

4.1 General

Guarantees of several kinds may be stated in the contract, for example on efficiency, heat (or steam) rate, output, or auxiliary power. Guarantees may also be required for characteristics such as governing (control) system functions, vibration level or noise.

All guarantees with their provisions shall be stated and formulated completely and without ambiguity.

4.2 Turbine plant thermal efficiency or heat rate or steam rate

The guaranteed heat (or steam) rate is given on the assumption that the acceptance tests shall be in accordance with the provisions of IEC 953, including the need for agreement of correction procedures. The contract shall state whether IEC 953-1 or IEC 953-2 will be used. The turbine plant thermal efficiency or heat rate or steam rate guarantee may, for example, be confined to one specified load or to their weighted values at a series of loads, in accordance with the terms of the contract.

Where the regenerative feed water heaters are not included in the turbine supplier's contract, the purchaser shall preferably supply with his specification a diagram of the feed water heating system with sufficient information to enable the heat rate guarantees of the complete set to be formulated. Alternatively, the supplier shall state in his tender the number and distribution of the feed water heaters, the feed water heater terminal temperature differences, and the pressure differences between the turbine and the heaters, which have been used in formulating the guarantee.

Similar steps shall be taken in wet-steam turbines where either the moisture separators, or the reheaters, or both, are not included in the turbine contract.

Where regenerative feed water heaters are included, the requirements in clause 19 shall also be applied.

The turbine supplier shall be given the opportunity either of adjusting his guarantee in the contract stage, should the performance of plant not in his supply, such as heaters, valves, piping, or pumps, differ from that on which his guarantee was based, or of applying agreed corrections to the thermal acceptance test results.

4.3 *Output or steam flow capacity*

The turbine shall be demonstrated to provide its rated output, or alternatively its rated steam flow capacity, when the terminal conditions are as specified in the contract. The test shall be carried out in accordance with the provisions of IEC 953.

4.4 *Auxiliary plant power*

If a guarantee is given on the power consumption of continuously running auxiliary plant, a list of such plant items shall be agreed. The power consumption of each such item shall be either measured when the turbine is at specified output and specified terminal conditions or agreed between the purchaser and the supplier.

4.5 *Steam tables*

The steam tables or formulation to be used for the guarantees and the computation of test results shall be consistent with the International Skeleton Tables established at the Sixth International Conference on the Properties of Steam (ICPS) in 1963, and should preferably be based on the 1967 International Formulation Committee (IFC) Formulation for Industrial Use that was approved at the seventh ICPS in 1968.

They shall be agreed upon by the purchaser and the supplier, and shall be stated in the contract.

4.6 *Tolerances*

Commercial tolerances are not within the scope of this part.

4.7 *Ageing*

Any allowance to be made for the effect on the corrected test heat rate, steam rate or thermal efficiency due to lapse of time since first synchronization shall be made with prior agreement between purchaser and supplier, and shall be in accordance with the provisions of IEC 953-2.

5 *Governing (control)*

5.1 *Governing (control) system*

5.1.1 The turbine governing (control) system shall be capable of controlling the speed from standstill upwards. This control may be manual or otherwise.

5.1.2 For turbines driving a generator, the turbine governing (control) system shall also be capable of controlling:

- a) speed at all loads between no-load and full load inclusive, in a stable manner when the generator is operated isolated;
- b) the energy input to the interconnected system, in a stable manner, when the generator is operating in parallel with other generators (see 6.1.1).

5.1.3 The governor and its system shall be so constructed that failure of any component will not prevent the turbine from being safely shut down.

5.1.4 If the governing (control) system is of the electro-hydraulic type, then the electronic equipment additionally shall comply with the requirements specified in annex A.

5.1.5 The governor and the steam valve operating device shall be so designed that the instantaneous loss of any load up to the maximum obtainable under rated conditions or the abnormal conditions specified in 6.3.1 shall not lead to transient overspeed sufficient to cause the turbine to trip.

5.2 *Speed and load adjustments*

Unless otherwise stated in the contract, when operating at zero load, the speed of the turbine shall be adjustable as follows:

- when driving a generator, within at least the range from 5 % below to 5 % above rated speed;
- when driving a mechanical load, within the range to be agreed.

The minimum time required for speed and load adjusting devices to change the set point from zero to rated load at rated speed shall not normally exceed 50 s, but may be agreed between purchaser and supplier. Means shall be provided for adjustment of the set points.

5.3 *Governor characteristics*

The speed droop and deadband characteristics required for mechanical and electro-hydraulic governing systems are as required by table 1.

Numerical values are given for guidance. Special consideration shall be given to the needs of industrial turbines and for turbines for generating purposes where the rated output is more than 5 % of the system capacity.

5.4 *Valve testing*

For industrial type turbines, and for those turbines which have a single stop valve or governing valve, or where the governing valves are operated by a single actuator, means shall be provided whereby the emergency and governing valves may be partially stroked to check freedom of movement, without interrupting operation of the turbine.

For other types of turbine, the control gear shall be provided with means of full-closure on-load testing of any of the valves specified in 7.5 in turn.

The supplier shall state the extent of any output restriction involved.

5.5 *Overspeed trip (emergency governor)*

5.5.1 In addition to the speed governor, the turbine and generator shall be protected against excessive overspeed by a separately actuated overspeed protection system which operates the trip.

The overspeed trip shall operate normally at a speed of 10 % in excess of rated speed, with a tolerance of 1 % of rated speed in each direction (i.e. at a speed not more than 11 % nor less than 9 % in excess of rated speed).

In exceptional circumstances (for example, in order to conform to the requirements of 5.1.5), and by agreement, it may be necessary to provide a normal trip setting above 10 % (with the 1 % tolerance above and below the selected figure). In any case, should the speed governor fail in the event of a sudden load rejection, the overspeed trip should operate at a speed which is sufficiently low to limit the maximum overspeed to a safe value, i.e. to prevent any damage to any part of the turbine or driven machinery; or to any electric motors which may remain connected to the generator following load rejection, and to the equipment which they drive. The overspeed trip settings shall be stated by the supplier in the operating instructions.

5.5.2 For industrial and other small turbines, an overspeed trip system shall be provided, independent of the governor, the operation of which shall close the emergency stop valves and governing valves.

5.5.3 For all other types of turbine, at least two entirely separate overspeed trip devices shall be provided, functionally independent of the governor, the operation of either of which shall close all the emergency stop valves and governing valves.

It shall be possible, while the set is in operation at rated speed, to demonstrate the correct functioning of each of the overspeed trip devices while the set is protected by the second device against overspeed, and without affecting the position of the main steam valves. Means shall be provided so that, when one of the overspeed devices is being tested for correct functioning, it shall not be possible to block or impede the second device from operation if called upon.

5.5.4 For industrial type turbines, the overspeed trip system shall be capable of being reset without stopping the turbine.

5.5.5 For all other types of turbine, the overspeed trip mechanism shall be capable of being reset when the turbine speed has decreased to a speed not lower than the rated speed.

Table 1 – Governor droop and deadband characteristics

Governor type	Mechanical			Electrohydraulic		
Turbine MCR, MW	Up to 20	20 to 150	Over 150	Up to 20	20 to 150	Over 150
Overall droop, %	← 3 to 5 →					
Incremental droop, % { a) range (0 to 0,9) x MCR b) range (0,9 to 1,0) x MCR	Maximum = No limit and Minimum = 0,4 x overall droop			a) 3 to 8 b) Not greater than 12		
Average incremental droop over the range 0,9 MCR to MCR*, %	← Not greater than 15 →			← Not greater than 10 →		
Deadband, % of rated speed	0,40	0,20	0,10	0,15	0,10	0,06

* For nozzle governed (controlled) turbines employing partial arc admission, the average value of droop over the range 90 % to 100 % of the output controlled by any nozzle group governing valve, other than the last, shall not exceed three times the overall droop.

6 Operation and maintenance

6.1 Normal operation

6.1.1 For normal operation, the characteristics of the turbine shall be such that the turbine and driven machine can be run in parallel with any existing machines provided the latter can run correctly in parallel with each other and possess no abnormal features either individually or collectively.

6.1.2 Start-ups of superheat turbines can be classified into various categories according to the thermal condition of the turbine at the time. The true ruling criteria are the metal temperatures to which the various components (such as the HP inner casing) have cooled, but it is also usual to classify the starts in terms of the elapsed time after previous operation; the features which follow give typical correlations, and may be taken for guidance.

Typical start-up categories are:

- a) cold start, after a shut-down period exceeding 72 h (metal temperatures below approximately 40 % of their fully-load values in °C);
- b) warm start, after a shut-down period of between 10 h and 72 h (metal temperatures between approximately 40 % and 80 % of their full-load values in °C);
- c) hot start, after a shut-down period of less than 10 h (metal temperatures above approximately 80 % of their full-load values in °C);
- d) very hot restart, within 1 h after a unit trip (metal temperatures at or near their full-load values).

6.1.3 The purchaser shall specify the following duties for which the turbine shall be designed:

a) the number of starts in each of the above categories;

NOTE - In the absence of the purchaser's requirements in this respect, the supplier shall state the number of each type of start for which the turbine is designed. A schedule, typical of a turbine intended for ultimate two shift operation, may include:

- 100 cold starts;
- 700 warm starts;
- 3 000 hot starts.

b) the number of major load cycles;

c) the rate of load change required for each class of significant load cycle, taking into account any limitations in other parts of the plant, such as the steam generator.

NOTE - The permitted rate of load change, and the significance of a load cycle, are related to the characteristics of the steam generator (see 6.1.4) and to the mode of turbine operation during each load change (i.e. throttle-governing (control) or nozzle-governing (control), as well as to the particular turbine design. Rapid changes of steam temperature within the turbine, which during load changes can depend on all of these factors, may lead to undesirably high thermal stresses in some components, and hence to excessive reduction in their life.

In addition to the major load cycles defined, further minor variations from stable conditions (i.e. increments of less than 10 % of MCR) may be accepted, and these need not be stated.

6.1.4 The purchaser shall provide, bona fide, the characteristics of the steam generator, to include the variation in pressure and initial and reheat temperatures with steam flow rate, for all of the start categories, load cycles and shutdown regimes envisaged.

6.1.5 The purchaser shall specify whether a turbine by-pass system is to be employed and if so shall state its duties, steam conditions and flow rates, and by whom it shall be supplied.

6.1.6 The purchaser shall also specify the parameters of steam available from auxiliary sources.

6.2 *Limits of variation of rated conditions*

The turbine shall be capable of accepting variations from the rated conditions within the limits stated below:

a) *Initial pressure*

The average initial pressure at the turbine inlet over any 12 months of operation shall not exceed the rated pressure. In maintaining this average, the pressure shall not exceed 105 % of the rated pressure. Further accidental swings not exceeding 120 % of the rated pressure are permitted, provided that the aggregate duration of such swings over any 12 months of operation does not exceed 12 h (but see note at the end of 6.2).

NOTE - See definition of rated steam conditions in 3.3.

An increase in initial pressure will normally permit the turbine to generate power in excess of its normal rating, unless action is taken through the control system to restrict the steam flow rate. The generator and associated electrical equipment may be unable to accept such additional output, and undesirable stresses may also be imposed on the turbine; the purchaser shall accordingly provide load-responsive protective means to limit the turbine output under such circumstances.

The purchaser shall provide means to ensure that the turbine exhaust pressure before the reheater cannot exceed 125 % of the specified pressure at this point when the turbine is operating at its rated output.

b) *Initial, and where applicable, reheat temperature*

For rated steam temperatures up to and including 566 °C, the permissible variations are as stated in the succeeding paragraphs. For rated temperatures in excess of 566 °C, the permissible variations shall be the subject of agreement between the purchaser and the supplier.

The average steam temperature at any inlet to the turbine over any 12 months of operation shall not exceed the rated temperature. In maintaining this average, the temperature shall not normally exceed the rated temperature by more than 8 K. If, exceptionally, the temperature exceeds the rated temperature by more than 8 K, the instantaneous value of the temperature may vary between this figure and a value of 14 K in excess of the rated temperature, provided that the total operating time between these two limits does not exceed 400 h during any 12 months operating period. Operation between limits of 14 K and 28 K in excess of the rated temperature may be permitted, for brief swings of 15 min or less, provided that the total operating time between these two limits does not exceed 80 h during any 12 months operating period. In no case shall the temperature exceed the rated temperature by more than 28 K (see note at the end of 6.2.)

Should steam be supplied to any terminal point on the turbine through two or more parallel pipes, the steam temperature in any of these pipes should not differ from that in any other by more than 17 K, except that during fluctuations not exceeding 15 min in duration within any four-hour period, a temperature difference not exceeding 28 K shall be admissible. The steam temperature in the hottest pipe shall not exceed the limits given in the preceding paragraph.

c) *Back-pressure turbine exhaust pressure*

The average exhaust pressure shall not exceed the specified exhaust pressure over any 12 months operating period.

In maintaining this average, the exhaust absolute pressure shall not exceed the rated pressure by more than 10 % nor drop more than 20 % below it.

d) *Condensing turbine exhaust pressure*

The turbine shall be capable of operating with any variation in exhaust arising from the range of cooling water temperature or flow specified, or alternatively the range of exhaust pressure specified. The supplier shall declare any limitations in these respects.

e) *Speed*

The turbine shall, unless otherwise agreed, be capable of operating without restriction on duration or on output between 98 % and 101 % of rated speed.

Operation at speeds further removed from rated speed shall not be permitted except by agreement.

NOTE - The limitations placed on variations of initial pressure and initial temperature in 6.2 a) and 6.2 b) respectively are appropriate for a turbine supplied with steam from a fossil-fired boiler or other high-temperature source.

For a turbine supplied with steam at or near saturated conditions, for example from a nuclear reactor, the limitations to be placed on initial steam conditions shall be agreed between the purchaser, the reactor supplier and the turbine supplier.

6.3 *Abnormal operation*

6.3.1 The purchaser shall specify his requirements if operation is required in any of the following categories:

- a) part of the condenser cooling section isolated;
- b) some or all of the feed water heaters out of service;
- c) overload, and how it shall be achieved;
- d) any other operating mode which imposes unusual conditions.

6.3.2 The supplier shall state any limitations arising from specified abnormal operation. This may include such matters as structural loading or adjustment in output power, and they shall include the permitted duration for such limitations.

6.4 *Installation conditions*

6.4.1 The purchaser shall specify whether the installation is indoors or outdoors, with or without a roof, and the conditions in which the turbine unit must operate, including maximum and minimum temperatures, relative humidity, unusual dust problems, precipitation and wind speed (if outdoors), and other related factors.

6.4.2 The purchaser shall provide any relevant data concerning seismic conditions for which the plant is to be designed.

6.5 *Maintenance*

When requested by the purchaser, the supplier shall give information on the anticipated frequency and scope of maintenance for the turbine plant.

6.6 *Operating instructions*

The supplier shall provide operating instructions wholly relevant and free from ambiguity, which will enable the plant which he has supplied to be operated safely.

The instructions shall include reference to all limitations on plant operation, and may also include the supplier's requirements for steam purity.

7 Components

7.1 Materials and construction

All materials, components, and welding used in the construction of the machine, and all piping, mounting, fittings and ancillary apparatus shall, so far as is reasonable, meet the requirements of the appropriate national or international standards. The standards shall be specified in the contract.

7.2 Parts subject to high temperatures

a) Unstressed parts

The selection of material for parts not subjected to appreciable stresses at their operating-temperature shall be such as to avoid unacceptable deterioration of properties as a result of:

- i) internal structural or constitutional changes; or
- ii) reaction between the material and its environment.

b) Stressed parts

The materials used for stressed parts shall fulfil conditions stated under a) above. In addition, they should be selected on the basis of experimentally determined data which confirm that under the conditions of stress, temperature and time in which the components will be used, they will not crack or deform to a greater extent than is permissible.

7.3 Casings and pedestals

Casings, pedestals and supports shall be designed to withstand all normal and emergency service loads, allowable piping forces and moments, and movement caused by temperature. The casing design shall be such that thermal stresses in service are minimized. Turbine casings shall be adequately supported to maintain good alignment with the rotors.

Jackscrews, lifting lugs, eyebolts, guide dowels and special tools shall be provided where necessary to facilitate assembly and dismantling.

7.4 Rotors

7.4.1 Rotors when completed shall be dynamically balanced.

7.4.2 The critical speeds of the combined turbine and driven machine shall be sufficiently removed from the rated speed to avoid any adverse effect on the operation of the unit over the range of speeds from 6 % below the rated speed to that obtained following a full load rejection when the speed governing system fails to operate.

Where the driven machine is not supplied by the turbine manufacturer, agreement shall be reached as to the party responsible for the critical speeds of the combined turbine and driven machine.

7.4.3 An overspeed test of each turbine rotor shall be carried out, preferably at the manufacturer's works. The overspeed test shall be at a speed exceeding by 2 % the maximum calculated overspeed that would occur if the speed governor failed and if the maximum overspeed were limited by the action of the overspeed trip device only. The duration of the overspeed test shall not exceed 10 min, and it shall only be performed once.

When the normal setting of the overspeed trip is at 10 % excess speed, the overspeed test shall not be in excess of 20 % above rated speed.

7.4.4 Rotors and their couplings (and gearing where used) shall be designed to withstand those conditions imposed by generator short-circuits, or by other specified disturbances within the electrical system.

The purchaser shall provide protection devices to reduce or eliminate the effect on the turbo-generator of any electrical fault on the system.

7.5 Valves

The turbine shall be provided with an appropriate number of governing (control) valves. These shall be suitable for controlling the initial steam supply to the turbine over the entire speed and load range. In addition, suitable emergency stop valve(s) shall be provided in series with these governing valves. The valves which first receive steam shall each be provided with a steam strainer located as closely as practicable, upstream of the valve. For small industrial type turbines, the emergency and governing (control) functions may be combined into a single valve.

On those turbines which operate with a reheat steam cycle, an appropriate number of reheat governing (control) valves shall be provided. Suitable reheat emergency stop valves shall be provided in series with these governing (control) valves. The valves which receive steam first from the reheater shall each be provided with a steam strainer located as closely as practicable upstream, except where:

- a) the first valve is of the swinging flap type (in which case the strainer shall be provided between the first and second valves), or
- b) reheat is carried out in a steam/steam reheater.

7.6 Main bearings and housings

- a) Journal bearings shall be transversely split with renewable liners, pads or shells.
- b) Thrust bearings shall be designed to accommodate thrust in either axial direction. The thrust bearing shall have provision for adjustment of rotor axial position during maintenance.
- c) It shall be practicable to renew all the bearings without dismantling any cylinder.
- d) Journal and thrust bearings shall be designed for pressure lubrication and to ensure proper drainage.

e) Bearing housings shall provide protection against the ingress of moisture or foreign matter and the leakage of lubricant.

f) To minimize the effects of electrical currents generated by electrostatic friction effects, the shafts of the turbine and the driven machine shall be earthed (grounded). In cases where these machines are supplied by separate suppliers, the purchaser and supplier shall agree to the location of the shaft earthing points.

For the smaller industrial turbines, earthing is not usually necessary.

7.7 *Cylinder and interstage glands*

Glands at the ends of the rotors and between stages shall be of suitable materials to minimize distortion or growth at the operating temperature.

The construction of the glands shall be such as to minimize damage to the rotor in the event of rubbing while in operation.

7.8 *Thermal insulation*

When specified, the turbine shall be insulated. The purchaser shall state the required outer surface temperature of the insulation material (not normally exceeding the ambient temperature by more than 40 K, but in accordance with national standards). The insulation shall be so designed that turbine maintenance is facilitated.

The purchaser shall state any limitation on insulation materials.

8 Foundations and buildings

The turbine supplier shall provide the purchaser with the relevant information (static and dynamic loads, outline drawings, seating details, forces and moments, permissible foundation deflections, thermal expansions, etc.) at the interface between his own design responsibility and that of the purchaser or his foundation designer, to enable design and construction of the total support system to proceed.

The turbine supplier shall ensure that the deflections, natural frequencies of vibration, and other properties of parts of the foundation designed or supplied by him will have no adverse effect on the operation of the plant over the range of speeds specified in 5.2 and 5.3.

Details of loads transmitted to the turbine, when in service and when not in service, including all piping forces and moments, shall be agreed with the turbine supplier.

Unless agreed otherwise, the purchaser shall provide a suitable foundation block, on which the turbine supplier shall be given the opportunity to comment at the design stage. The natural frequencies of vibration of the foundation should not correspond to any low multiple of the operating speed of the unit.

Sufficient space and necessary openings in the foundations and building structure shall be provided for installation of the equipment. Suitable openings shall be provided in the building to admit the equipment. The purchaser shall provide sufficient space round the equipment for servicing, including space for removing the rotors and setting down the upper halves of the turbine casings.

Where ancillary equipment connected to the turbine (for example, moisture separators and reheaters) is mounted on a separate foundation supplied by others, the turbine supplier shall specify the permissible movement relative to the turbine foundation.

9 Feed pump drives

9.1 Information required

Feed pumps may be driven by a variety of means, which can differ in their thermodynamic influence on the cycle. The turbine supplier will usually require information, as listed below, before design details or the determination of heat rate can be finalized.

9.1.1 Drive by auxiliary turbine

Where the pump is driven by an auxiliary turbine using steam extracted from the main turbine, or where exhaust steam from the auxiliary turbine discharges into the main turbine or its system:

- i) when the main turbine supplier supplies the feed pump and its driving turbine, the purchaser shall, at an early stage, provide the turbine supplier with information showing the required feed pump generated head as a function of feed water flow rate;
- ii) when the main turbine supplier supplies the separate turbine driving the feed pump, but does not supply the pump, the purchaser shall, at an early stage, provide the turbine supplier with information showing the variation of the required pump input power and speed and feed pump generated head, as functions of feed water flow rate;
- iii) when the main turbine supplier supplies neither the separate turbine driving the feed pump, nor the pump, the purchaser shall, at an early stage, provide to the main turbine supplier sufficient information to enable the feed water enthalpy rise across the pump and the steam flow to the separate turbine to be derived, over the range of feed water flow rate.

In i) and ii) above, this information shall cover the range from the minimum load on the main turbine at which the turbine-driven feed pump is to be independently capable of meeting the feed flow requirements, up to the maximum feed water flow rate for which the pump and its driver are to be designed.

An additional margin of power and speed, above that required for the maximum power rating, shall be allowed before fixing the capability of the auxiliary turbine; the amount of this margin shall be agreed between the purchaser and the main turbine supplier.

If the main turbine supplier does not supply inter-connecting piping conveying steam from the supply point on the main turbine, or from the main steam pipes (or from other sources), to the feed pump turbine, the purchaser shall state to the main turbine supplier the drops in steam pressure and temperature to be allowed in this piping.

9.1.2 Drive by electric motor

Where the pump is driven by an electric motor, sometimes directly, sometimes through a speed-changing gear, and sometimes through an interposed hydraulic coupling:

- i) when the turbine supplier supplies the whole of this equipment, the purchaser shall, at an early stage, provide the turbine supplier with information showing the required feed pump head against feed water flow rate;
- ii) when the turbine supplier supplies the driving equipment but not the pump, the purchaser shall, at an early stage, provide the turbine supplier with information showing the required pump power (measured at the pump inlet coupling) and feed pump generated head as functions of feed water flow rate and also the pump maximum speed;
- iii) when the turbine supplier does not supply the feed pump, motor, speed-changing gear, or hydraulic coupling, the purchaser shall, at an early stage, provide the turbine supplier with information showing the enthalpy rise in the feed water as a function of feed water flow rate.

9.1.3 Margins on pump duty

In all instances, the specified feed pump flow rate shall include attemperation water requirements for superheater, reheater, and turbine by-pass, where these are provided.

9.2 General

9.2.1 Where the feed pump is driven by an auxiliary turbine, the auxiliary turbine supplier and the pump supplier shall agree all the relevant interface information, including the direction of rotation. Consideration shall be given to the supply arrangements for lubricating oil, control fluid, sealing water to the feed pump and gland sealing steam to its driving turbine, bearing in mind that these may need to be separate from those of the main turbine. The requirement for fitting turning gear shall be agreed between the auxiliary turbine and feed pump suppliers.

9.2.2 Consideration shall be given to any requirement for preventing or restricting reverse rotation of the feed pump.

10 Turbine auxiliary systems

10.1 Lubricating oil

The turbine shall have a main oil pump which shall be driven mechanically by the turbine itself or (by agreement) by an electric motor.

An auxiliary oil pump, driven from a source entirely separate from the main oil pump, shall be provided to operate when starting up or shutting down the turbine, and to come into operation automatically as a replacement to the main pump in the event of low oil pressure, to enable the turbine to remain in service. Provision shall be made to on-load test the auto-start of all back-up lubricating oil pumps by simulating low oil pressure.

An emergency standby pump, preferably d.c. motor driven, of adequate size to permit a safe run-down of the set, shall be provided to start automatically in the event of the failure of an auxiliary oil pump or of its electrical supply; alternatively, by agreement, a gravity oil tank may be provided for this purpose.

A jacking oil system shall be provided to supply high pressure oil to each turbine and generator bearing, if this is necessary, to lift the rotors to reduce starting torque and bearing wear when barring (turning) or during starting.

Multiple oil coolers and filters shall be provided of sufficient capacity so that any one oil cooler or filter can be taken out of service with the set in operation. The inlet and outlet changeover valves to the coolers or filters shall be arranged so that they are not capable of shutting off the flow of oil to the bearings while the set is in operation. For industrial type turbines, single oil coolers and filters may be provided.

All pipes, valves, cooler bodies and filter bodies shall be of steel or other appropriate material. Brittle materials such as cast grey iron are not suitable. Pipe joints shall be welded wherever practicable.

Precautions shall be taken to minimize internal corrosion in oil tanks and drain pipes.

The supplier shall specify the properties of the lubricating oil to be used. When initial flushing is not carried out by the supplier, the oil used shall be to his approval.

The design of the lubricating system shall be such that during normal operation, the operating temperature of the oil at each main bearing drain will not, in general, exceed 75 °C. There are applications on small turbines where this temperature may be increased to 85 °C. Precautions shall be taken against fire caused by leakage of lubricating oil.

10.2 *Control fluid*

The fluid used in the control system and for operation of the steam valves may be either oil from the lubricating system, or fluid from an entirely separate system. The pumps supplying the separate control fluid shall be duplicated, with automatic changeover on failure of one pump.

Arrangements shall be made, if necessary, to sustain the pressure of the control fluid during the starting period of the standby pump.

When a fluid other than oil from the lubricating system is used, the fluid shall be to the supplier's approval. The same requirements regarding materials, pipe construction and the duplication of coolers and filters as in 10.1 shall apply unless otherwise agreed.

10.3 *Sealing system for rotor and valve glands*

The sealing system at the ends of the rotors and valve glands shall, unless otherwise agreed, be so arranged, for example by the provision of a gland steam condenser, that no steam issues into the turbine hall. Where appropriate, the control of sealing steam for the glands shall be fully automatic under all modes of operation. Relief valves shall be fitted to the steam pipework as necessary. When auxiliary steam is required, such as for start-up, the supplier shall state his requirements for the steam conditions and quantity.

10.4 *Drains*

Each turbine casing, steam chest, or other vessel, and all pipes conveying steam, including bled steam pipes to feed water heaters, shall be adequately drained at all points where water may accumulate.

Drainage shall normally be to a suitable drains vessel, and the drain pipes shall incorporate suitable valves, traps, or orifice plates before discharge into the drains vessel.

10.5 *Vents*

Vent piping shall be provided from the gland steam exhauster fan and lubricating system exhauster fan(s) to a specified outdoor location, or as agreed.

10.6 *Turning gear*

Turning gear (sometimes known as barring gear) shall be provided to rotate the rotor system slowly (continuously or discontinuously), if necessary, to limit thermal distortion of the rotor(s) when not turning under steam. Interlocks shall be provided, if necessary, to ensure that turning cannot commence until an adequate supply of lubricating oil is available and the drive is fully engaged. The turning gear shall disengage automatically when the turbine speed increases above the turning gear speed.

10.7 *Piping*

All piping for steam, water, oil, or air services shall preferably be in steel complying with the requirements of the appropriate international or national standard. The standards should be stated in the contract.

Welded joints shall be used wherever practicable. Other materials may be used by agreement between the purchaser and the turbine supplier.

The turbine supplier shall state the magnitude and direction of application of the pipework forces and moments, applied at the agreed major terminating points of his equipment, which are acceptable to his plant.

11 Instrumentation

11.1 General

Such instruments shall be provided as are necessary to enable the turbine to be reliably and efficiently operated and supervised.

The scope of instrumentation that is economically justified will depend on the rating of the turbine and the conditions under which it is to operate. The following requirements apply to large turbines.

11.2 Standard instruments

Where applicable, primary measuring elements for at least the following shall be provided:

a) Pressures

- initial and reheat steam inlets immediately upstream of the initial and reheat stop valves and strainers;
- extraction(s), for extraction turbines;
- extractions to feed water heaters;
- exhausts from each cylinder;
- lubricating oil supply to bearings;
- fluid supply to the control system.

b) Temperatures

- initial and reheat steam;
- steam at exhaust from high pressure and intermediate pressure cylinders;
- extractions to feed water heaters;
- oil at cooler outlet;
- oil in the bearing drains, or bearing metal.

c) Levels

- level of oil in main lubricating oil tank;
- level of fluid in control fluid tank.

11.3 Supervisory equipment

Equipment for measuring the following shall be provided:

- a) *Speed*: rotational speed of the turbine;
- b) *Load*: electrical output of the generator (frequently this instrument is not included in the turbine contract);
- c) *Rotor and pedestal movement*: axial differential movement of selected rotors, each relative to its casing or pedestal, measured at the end remote from the thrust bearing.

Axial movement of pedestals relative to the foundation;

- d) *Vibration*: vibration of pedestals or rotors. Rotor eccentricity, and the phase angle of the vibration, may also be required:

e) *Metal temperatures*: provision shall be made for the measurement of all metal temperatures or temperature differences considered necessary for the safe operation of the turbine, or for enabling stresses in turbine casing walls or other components to be assessed, to provide information on safe rates of run-up or load change;

f) *Valve position*: positions of all initial and reheat steam valves, unless otherwise agreed, except that only fully-open or fully-closed indication is required for reheat emergency valves;

g) For saturated steam turbines, which incorporate moisture separators and reheaters; reheating steam flow (or reheater drains flow), and levels in separator and reheater drain tanks;

h) In addition, equipment necessary to provide the alarm and trip initiating signals listed in clause 12 shall be provided.

11.4 *Additional instruments*

Additional primary measuring elements may be specified by the purchaser, or recommended by the supplier.

For large turbine plant the instrumentation may typically include:

- cooling water temperature;
- condenser pressure;
- pressures and liquid levels in various vessels;
- steam and water temperatures at inlet and outlet of feed water heaters and other heat exchangers;
- inlet and outlet pressures of feed pumps;
- condensate, feed water and initial steam flow rates.

NOTE - Primary measuring elements for such measurements may be supplied by others.

11.5 *Test measuring points*

For the purpose of carrying out performance tests for heat rate or other reasons, measuring points shall be provided for all test measurements and observations. These measuring points shall be additional to those required for the normal operation and control of the turbine, and shall be agreed between supplier and purchaser.

Agreement shall be reached upon responsibility for, and provision of, those required measuring points located at positions outside the contractual scope of supply.

12 **Protection**

12.1 *General*

The extent of protection which can be economically justified depends upon the rating of the turbine and the conditions under which it has to operate. The following requirements apply to large turbines.

12.2 Protection system - tripping

12.2.1 A separate and independent turbine protection system shall be provided. This system shall be so designed that in the event of a trip signal occurring, its operation shall result in the immediate closure of all steam valves (i.e. emergency stop valves, governing (control) valves, reheat emergency valves, and reheat governing (control) valves), and in the power closing of the non-return (check) valves (where these are fitted) in the cold reheat steam pipes, in the bled steam lines to the feed water heaters, and in other systems normally supplied with steam from the turbine; thereby enabling the turbine to run down safely in the event of an incident which could otherwise cause damage to the turbine or its auxiliary equipment.

12.2.2 The protection equipment shall be designed on a fail-safe principle, such that loss of control fluid pressure shall cause immediate closure of the emergency stop valves and the governing (control) valves.

12.2.3 Removal of the condition that has initiated the operation of the trip system shall not cause the trip gear to reset automatically, nor the steam valves to re-open. The trip system shall be arranged so that it can be reset only by the operator. Until the trip system has been reset, it shall be impossible to re-open any of the steam valves.

12.2.4 The trip system shall be based on, but not necessarily confined to, the following list of initiating devices, operation of any one of which shall cause operation of the trip system:

- a) overspeed trip (see 5.5);
- b) manual trip local to the turbine;
- c) emergency stop push-button, locally and remotely operated;
- d) high exhaust pressure trip;

NOTE - Increase in condenser pressure above a set value shall be arranged to actuate one (or more) alarms, which may be set at different pressures. Further increase in condenser pressure shall result in a unit trip.

- e) low steam inlet pressure trip (where required);
- f) low lubricating oil pressure trip;
- g) loss of speed governor trip (for electric governors);
- h) trips initiated by the generator or its auxiliary systems; for example loss of generator stator winding cooling water;
- i) electrically-operated trip automatically initiated by electrical fault operation.

12.3 Protection system - alarms

Alarms shall be raised, but the turbine shall not (unless otherwise specified) be tripped for:

- a) excessive thrust bearing wear;
- b) high steam temperature at the low pressure cylinder exhaust;
- c) excessive bearing temperature (oil or metal);
- d) excessive vibration.

12.4 Protection system - other devices

Other protection devices, which shall not, unless specified in the contract, initiate tripping of the turbine shall be provided. These include:

12.4.1 Low-pressure casing and condenser pressurization

The low pressure cylinders and the condenser shall be protected against excessive pressure by valves or relief diaphragms of sufficient size to keep the pressure within permitted limits.

12.4.2 Water ingress from the feed water heating system

Protection against water entering the turbine from the feed water heating plant shall be specified by the purchaser to the supplier of the feed water heating plant. The main features of such protection shall include at least:

- a) Each bled steam line from the turbine shall be arranged so that all the heater surface must be flooded before any water can flow to the turbine. The heaters should preferably be located lower than the turbine.
- b) For every feed water heater, there shall be two independent means of automatically preventing water from entering the turbine from the extraction system; the system shall be designed so that no single failure of equipment results in water entering the turbine.

In general, these independent means can be a combination either of the following items:

- 2) and either 1) i) or 1) ii),
or 3) and either 1) i) or 1) ii),
or 2) and 3).

- 1) i) Provision of gravity drainage from the heater, with open manometric seal, or

- ii) Provision of an automatic alternative drainage route, of large capacity, from the heater.

NOTE – 1) i) is to be preferred to 1) ii), if conditions permit its use.

- 2) Provision of automatic isolating valves in the bled steam lines between the turbine and the feed water heater, and in drain lines cascading into the heater.

- 3) Provision of automatic isolating valves for all sources of feed water to the heater. This will normally require an automatic by-pass around the heater.

NOTE – The time of operation of each of the automatic isolating valves required by 2) and 3) above, from receipt of closing signal to the fully closed position should be such that for water flows into the shell equivalent to the larger of:

- a) water flowing from two ruptured tubes (from tube ends), or
- b) water flow equivalent to 10 % of the heater tube side flow at MCR, the valve should be closed before the water has filled the usable storage volume between the high level alarm (which initiates the valve closure) and the automatic isolating valve.

Items 1) ii), 2) and 3) shall normally be initiated by high water level sensors in the heater shell, with suitable precautions to ensure reliable operation.

c) Non-return (check) valves, normally provided in extraction lines to limit speed rise on loss of load (see 19.3), should be located as closely as practicable to the turbine extraction points.

Isolating valves and power-closed non-return valves, where provided, shall be arranged for testing (by closing) while the plant is in operation.

Power-assisted and free-swinging non-return valves shall be arranged for checking for freedom while the plant is in operation.

d) Where more than one bank of heaters is supplied from a single bled steam line, then either each heater shall have its own valves, or, if the valves are in the common line, water from a flooding heater shall flow into the associated heater and completely flood it before it is possible for water to flood the common bled steam pipe up to the turbine.

e) Each heater shall be provided with high water level detector switches, in duplicate and each arranged for testing for correct operation while the plant is in operation. Operation of such switches shall initiate operation of the protective devices.

12.4.3 *Moisture separator and reheater overpressure*

The vessels containing the moisture separators and reheaters shall be protected against over-pressurization by suitable relief valves, bursting diaphragms, or other agreed means.

12.4.4 *Low steam inlet pressure unloader (if required)*

Reduction in steam inlet pressure to the turbine below a set value shall be arranged to close the governing valves and so to reduce the turbine load progressively down to an agreed low value. Restoration of steam inlet pressure shall not result automatically in reopening of the governing valves, unless otherwise agreed.

Further reduction in steam inlet pressure shall result in a turbine trip (see 12.2.4).

NOTE - Where it is intended that the turbine should operate at partial load, at controlled, reduced, initial steam pressure, the protective devices of the low steam inlet pressure unloader and the low steam inlet pressure trip (see 12.2.4) should be so arranged as to continue to protect the turbine against a rapid decrease in inlet steam pressure, but automatic reopening of governing valves during normal operation is permitted.

12.4.5 *Unwanted steam*

Protection against unwanted steam admission to the exhaust of the high pressure turbine is necessary if a turbine by-pass is used.

This is normally achieved by the provision of at least one non-return (check) valve.

13 Vibration

13.1 General vibration of parts of the turbine

The turbine shall be arranged to permit vibration measurements in service at or adjacent to each main bearing (see 11.3 d)); vibration may be measured on the bearing housing, on the shaft, or relatively between the shaft and bearing housing. This part does not specify limits for vibration.

The preferred criterion for the description of turbine bearing housing vibration is the vibration velocity; this is, for synchronous vibration, related to the peak-to-peak displacement by the formula:

$$2A = 450 V / f$$

where:

2A is the peak-to-peak displacement in μm , V is the r.m.s. vibration velocity in mm/s and f is the rotational frequency in Hz.

The preferred criterion for the description of shaft vibration is the peak-to-peak shaft displacement.

13.2 Vibration measured at the bearing housing

Values of vibration velocity, measured in a radial direction at the bearing housing, of 2,8 mm/s or better, are usually obtainable for turbines in good balance, running under steady conditions at their specified operating speeds, but it may be possible for a turbine to continue in satisfactory operation at higher values.

Peak-to-peak displacements corresponding to this figure (which is in accord with Quality Band A of Class IV in ISO 2372) are given in table 2.

Table 2

Rated turbine speed (Hz)	Peak-to-peak displacement measured at the bearing housing (μm)
16,67	75
25	50
30	42
50	25
60	21
100	12
200	6

NOTE - The displacements at other speeds can be derived from the relationship:

$$\text{speed} \times \text{displacement} = 1\,250 \text{ (in the units quoted).}$$

13.3 *Vibration measured at the shaft*

Shaft vibration is usually measured relative to the bearing housing; in any case, the vibration measurements shall be carried out in accordance with ISO 7919-1. Vibration measured on the shaft is likely to be considerably greater (by a factor of 2 or more) than that measured at the bearing housing, depending on the nodal pattern of the shaft, the axial position of the pick-up, the bearing design and other factors.

14 Noise

14.1 *Noise emitted by the individual plant components*

The noise of machinery is measured on an imaginary surface around the machine, at 1 m from the machine surface and at a height of 1,2 m above the level of the floor, walkway, or other position provided for personnel access.

The surface noise level is defined as the maximum 'A'-weighted r.m.s. sound pressure level, measured on the slow response of a sound level meter complying with IEC 651, type 1, with the microphone positioned as described above.

14.2 *Noise level in the vicinity of the turbine unit*

The noise level in the vicinity of the steam turbine unit depends upon many factors such as the noise power generated by the various turbine components, the noise power generated by components of other plant in the station, the relative location of the turbine and the other plant components, and the acoustics of the surrounding area and building, including the amount of sound-attenuating material present.

When all of the above factors are within the turbine supplier's scope, the purchaser may state to the turbine supplier his requirements regarding the permissible noise level in the vicinity of the turbine. When the factors are not all within the turbine supplier's scope, it may be necessary for the purchaser, the turbine supplier, and those responsible for the other factors, to cooperate to meet the purchaser's requirements. Suppliers of other components or plant in the vicinity of the turbine shall themselves be responsible for the noise it produces.

If these requirements are not met by the basic design of plant, they may be achieved by the supply of suitable acoustic screens or enclosures.

15 Tests

15.1 *General*

All the tests required by this part shall be carried out in accordance with the stated provisions.

Any further tests required by the purchaser, and the extent of any witnessing by the purchaser or his representative, shall be stated in the purchaser's specification.

15.2 *Hydraulic tests*

As part of the Quality Assurance Program, all parts subjected in normal service to a pressure above atmospheric shall be tested hydraulically so that the pressure loads shall be at least 50 % in excess of the maximum that could occur at any load with rated terminal conditions (as defined in 3.3). The hydraulic test may, by agreement, be omitted where, in service, leakage would not be to atmosphere. The hydraulic test may also be omitted by agreement when the manufacturer can, by other means, satisfy the purchaser of the integrity and suitability of the component.

15.3 *Performance tests*

The extent of any performance tests required shall be stated in the purchaser's specification, together with the extent of the supplier's expected participation.

Thermal acceptance tests shall be carried out in accordance with IEC 953-1 or IEC 953-2.

Speed and load governing tests shall be carried out in accordance with IEC 1064.

15.4 *Test results and data*

The supplier shall make available to the purchaser such certificates or reports as may be necessary to confirm that the objectives of all tests specified in the contract have been achieved.

16 *Delivery and Installation*

16.1 *Transport to site and temporary protection*

Before shipping from the works, all turbine components shall be suitably protected against corrosion, stress corrosion and handling damage during transport to site and any storage period before installation. Storage conditions and duration shall be specified and agreed between the purchaser and the supplier.

16.2 *Erection and commissioning*

The erection and commissioning procedures shall be in accordance with recommendations and instructions issued by the supplier either on drawings or by other means. It is recommended that where erection and commissioning do not form part of the contract, the purchaser should, as a minimum, use the services of the supplier's supervisor.

17 *Design Information to be supplied by the purchaser*

17.1 *General*

The purchaser will normally provide a detailed specification of his requirements to the supplier. It is recommended that the requirements or other relevant information include at least those listed below.

17.2 Characteristics of the turbine and its accessories

- a) Rated output as defined in 3.5 at generator terminals or at the turbine coupling.
- b) Weighting factors for thermal performance guarantee purposes, when required in pursuance of the requirements of 4.2.
- c) Speed of rotation, or system frequency, and operational speed range required.
- d) The total required running hours.
- e) Details of turbine location and any physical limitations.
- f) Any seismic conditions to be taken into account.

17.3 Steam and water conditions

- a) Rated steam conditions at the inlet to each set of turbine stop valves at the rated output and maximum steam conditions.
- b) Steam pressure at each exhaust flange of the steam turbine at the rated output.

NOTE - This includes the pressure at the turbine exhaust flange when the turbine supplier does not supply the condenser. When the turbine supplier also supplies the condenser, the information required is as in 17.4.

- c) For a fossil-fired plant, if the turbine is arranged for reheating between cylinders, and the reheater is not supplied by the turbine supplier:

- the cold reheat pressure(s);
- the pressure drop(s) in the reheater(s), and
- the set pressure(s) for safety valves on reheat system(s).

- d) If the turbine is provided with an external water separator, not supplied by the turbine supplier:

- the pressure drop in the steam;
- the efficiency of water separation;
- the destination of the separator drains;
- the set pressure of the safety valves or other devices (see 12.4.3), if they are not within the turbine supplier's scope.

If a water separator is followed by either single-stage or multi-stage steam/steam reheaters, not supplied by the turbine supplier:

- the pressure drop in the reheated steam;
- the pressure drop in the reheating steam pipe(s);
- the terminal temperature difference of each reheater stage;
- the destination of the reheater drains.

Where appropriate, these parameters shall be defined as a function of steam flow rate.

- e) If water is injected for temperature control of either initial or reheat steam:

- the source of supply, the rate of flow and the enthalpy of the water.

- f) If make-up water is to be supplied to the condenser for purging and boiler losses:
 - quantity and temperature of the water.
- g) If steam is required to be extracted for heating or other auxiliary purposes:
 - the flow rates and pressures required, the destination and enthalpies of the drains, whether the extraction pressure is to be controlled, and whether account is to be taken of such extractions in the guarantees.
- h) For low pressure steam supplied to a mixed-pressure steam turbine:
 - pressure;
 - mean temperature (or dryness fraction) and range;
 - steam flow rate;
 - method of control of steam input;
 - maximum power output required with high-pressure steam only.

NOTE - The supplier may require that the high-pressure steam flow does not fall below a value which he will specify.

- i) Availability and conditions of steam from auxiliary sources, for example for gland sealing at start-up.
- j) The chemical characteristics of the steam supply.
- k) For boiler feed pumps, the purchaser should provide the information listed in clause 9, together with all other information necessary for the thermodynamic and mechanical integration of the plant. Where possible, the information should provide details of the variation of these parameters with feed water rate or turbine output.

NOTE - In items c), d), e) and g) above, some exchange of informations will be required between the purchaser and the supplier, since the final design of equipment not in the supplier's scope will be affected by the pressure distribution in the final turbine design.

17.4 *Conditions for condensers and coolers (where this equipment is in the supplier's extent of supply)*

- a) Source of supply and quality of cooling medium, or heat exchange surface material to be used, and cleanliness factor to be used in the design.
- b) Maximum and minimum temperatures of the cooling medium, and the average temperature over the annual period.
- c) Any limitation on quantity of cooling medium available, or on permissible temperature rise.
- d) Maximum and minimum pressures at terminal points of cooling water system and pressure drop between them.

17.5 *Applications: installation and mode of operation*

- a) Particulars of the driven machine (if not supplied by the turbine supplier):
 - name of manufacturer;
 - complete dimensions of outline, interface, and holding-down arrangements;
 - full statement of relevant characteristics, including all normal or abnormal torques absorbed, and any axial thrust or journal bearing loads to be absorbed by the turbine;

- requirements for auxiliary services such as lubricating oil and cooling water;
- if the machine is driven through a gearbox, the speed of the output shaft;
- any requirements regarding balancing, alignment, provision for expansion, or other matters which can influence satisfactory operation of the assembled unit.

NOTE - The direction of rotation shall be agreed with the turbine supplier.

b) The nature of the load to be carried by the turbine, and the expected pattern and mode of operation.

c) The number, nature, and intensity of disturbances of the electrical system giving rise to abnormal torques.

The manufacturer of the generator, if not the same as the supplier of the turbine, shall provide to the turbine supplier details of the abnormal torques thereby imposed on the turbine; determination of these abnormal torques may require collaboration between the generator and turbine manufacturers.

d) The relevant factors affecting the operation of the turbine for example:

- 1) operational duty (see 6.1.3);
- 2) adoption of sliding pressure (see 3.10);
- 3) maximum required rate of load pick-up (see 6.1.3 c));
- 4) temporary abnormal operating conditions (see 6.3.1);
- 5) characteristics of the steam generator (see 6.1.4);
- 6) capacity of turbine by-pass system, if utilised (see 6.1.5).

e) The relevant factors affecting the economic optimization of the plant. These include the purchaser's evaluation figures to enable optimization of the turbine itself and of its condensing plant to be carried out.

For fixed initial steam conditions and steam flow rate, output can be increased and heat rate reduced, by judicious selection of various turbine plant parameters, including those relating to the condenser and its cooling water system.

The purchaser should state the figures he will use in his evaluation for:

- the benefit to him and one unit improvement in guaranteed heat rate;
- the cost to him of one additional kilowatt of auxiliary electrical power not already allowed for in the heat rate guarantee;
- the incremental cost to him of one unit of volumetric flow of cooling water and of make-up water;
- any other plant characteristics or dimensions which he will take into account.

f) Proposed control system defining those functions (e.g. starting and synchronizing, loading, shutting down, etc.) which are to be carried out manually from local or remote control positions and those to be carried out automatically).

g) The information listed in A.6 (annex A) if an electronic governor is required.

h) Installation conditions (see 6.4).

- i) Thermal insulation requirements (see 7.8).
- k) Permissible noise level (see clause 14).
- l) Additional instrumentation required (see 1.4).
- m) Whether low steam inlet pressure unloader (see 12.4.4) is required.

17.6 Foundations

If the purchaser is responsible for design of the foundation, he shall supply the turbine supplier at an early date with an outline drawing of the foundation based on information provided by the supplier in clause 8.

17.7 Terminal points

Terminal points of the plant to be supplied.

17.8 Delivery site conditions

- a) Point of delivery.
- b) Conditions affecting transport and access to site, facilities available on site, and any requirements for extended periods of storage.

17.9 Tests

Extent of performance testing (see 15.3).

18 Design information to be provided by the supplier

The supplier shall provide detailed information of his plant to the purchaser. It is recommended that at least the following items are included.

18.1 For stability of the turbine and for the mechanical design of the terminal points and pipework systems, the forces and moments from the principal steam pipes have to be limited. The supplier shall furnish adequate information to allow the purchaser to design the pipework systems in accordance with these requirements.

Similar information may be required in respect of the feed water piping where the feed water heaters or similar plant are within the supplier's scope.

18.2 For the relevant operating conditions, the thermal expansion of the terminal points.

18.3 For all pipe connections to the purchaser's pipework systems, dimensions of the terminal points, together with weld preparations and welding recommendations.

18.4 A recommended time schedule for the necessary interchange of technical information and drawings, to integrate the turbine-generator and its association equipment into the overall plant design.

18.5 Requirements for the steam conditions and quantity, for auxiliary steam for gland sealing during start-up.

18.6 Information on turbine foundations as detailed in clause 8.

19 Turbine plant with regenerative feed water heating

19.1 *Exchange of information*

Turbines for electrical power generation are usually arranged for regenerative feed water heating. The basis of the arrangement (see clause 4) and the relevant details, indicated below, shall be agreed between the purchaser and the supplier for one or more specific loads.

a) The number of bled-steam feed water heating stages, and which of them are to be provided:

1) from the main turbine; and

2) from any auxiliary turbine which may be supplied for driving other equipment, such as a boiler feed pump or auxiliary generator or similar plant.

b) The number and arrangement of individual heat exchanger vessels for each stage of feed water heating; and whether each vessel is supplied independently from a turbine tapping point, or from a header which supplies steam to all vessels of the same feed water heating stage.

c) The position of feed pumps in the feed water heating cycle, the pressure of the feed water at the discharge of each pump, and the rise in enthalpy of the feed water across each pump.

d) The desired feed water temperature at the appropriate terminal point, and the permissible deviation from the desired value.

Also, whether the final feed water temperature can be allowed to vary naturally with turbine load and, if not, the purchaser's requirements in this respect.

e) The method of cascading heater drains, and at which point or points (if any) the drains are pumped forward into the feed water system.

f) The terminal temperature difference for each heater, i.e. the difference between the saturation temperature of the steam in the heater and the temperature of the feed water leaving the heater.

NOTE - If there is de-superheating of the bled steam before it is admitted to the saturation zone of the feed water heater, the complementary feed water heating in the de-superheater must be taken into account.

g) The terminal temperature difference for each drain cooler (other than flash type), whether independent or integral with a bled steam heater, i.e. the difference between the temperature of the heater condensate leaving the drain cooler and the temperature of the feed water entering the drain cooler.

h) The rise in enthalpy of the condensate over any heat exchanger(s) in the feed water system not provided by the supplier.

j) The pressure drop from each extraction outlet on the turbine to the heater, or the drop in saturation temperature from extraction outlet to heater.

- k) The type and the location in the system of the bled steam evaporator (if provided), the quantity of make-up water required, the blow-down allowances for the evaporator, and the enthalpy of the raw water entering the evaporator.
- l) If the condensate from auxiliary plant is to be dealt with by the feed water heating system: the quantity and the enthalpy of such condensate, and its point of introduction into the feed water heating system.
- m) Particulars of any operating condition governed otherwise than by the output of the turbine, for example, deaerator pressure when a minimum value is specified, together with the source and conditions of any alternative steam supply available to satisfy such requirements.
- n) Where steam is supplied for feed water heating purposes from sources other than the main turbine: the pressure, enthalpy, and flow rate from each source, and the destination of the condensed steam. Similarly, where heat is supplied by media other than steam, the relevant details.

19.2 *Inclusion of the feed water heating system performance into the turbine guarantee*

When the turbine supplier supplies the feed water heating system, its performance shall be included in the guarantee of performance, unless otherwise agreed.

When the turbine supplier does not supply the feed water heating system, the information listed in 19.1 shall be stated in the guarantee of performance.

The turbine supplier shall be given the opportunity of adjusting his guarantees should the feed water heating system finally agreed upon differ from the system on which the guarantee was based.

19.3 *Provision of non-return valves in bled steam pipes from the turbine*

The supplier shall determine the amount of overspeed which the turbine will experience due to entrained steam, resulting from a loss-of-load incident or a turbine trip.

The number and type of non-return (check) valves to be placed in the bled steam extraction pipes from the turbine shall, when the feed-heating plant is not supplied by the turbine supplier, be agreed between the purchaser and the turbine supplier, and will be based upon the overspeed calculations.

It may be possible to eliminate non-return (check) valves from some extraction lines, provided that the quantity of steam which could return to the turbine has been evaluated and that the resulting effect on overspeed is acceptable.

Annex A **(normative)**

Electronic governors

A.1 General

A.1.1 Scope

This annex covers the electronic section of electro-hydraulic governing (control) systems and overspeed protection equipment used on steam turbines. The requirements of clause 5 shall also be observed where applicable.

A.1.2 Classification of governing (control) systems

A.1.2.1 Electronic governors are classified as follows to distinguish between the differing standards of performance, particularly reliability, required for various applications.

Type A: Fault-tolerant systems, in which at least one fault can be detected and repaired with no loss or only limited loss of system availability, and no loss of overspeed limiting capability. Such governing (control) systems may, for example, have three parallel redundant principal processing paths in which a failure in one path, detected by comparison, will give an alarm, and in which control will be maintained by voting arrangements between the paths.

Type B: Systems in which faults will be detected and will result in unloading or tripping of the unit for a proportion of single faults including all those resulting in a loss of overspeed limiting capability. Such governors may, for example, have two processing paths or one path with performance monitoring.

Type C: Systems with the same characteristics as type B, except that the governing (control) system output may be placed in a "hold" state for certain fault conditions in preference to unloading or tripping the turbine. In this state, the governing (control) system will make no contribution to limiting overspeed, although the system output may be manually controlled.

Type D: Simple governing (control) systems, in which failures will probably cause a complete loss of availability.

A.1.2.2 Governors may also be classified according to their interface with the steam admission valve hydraulic relays.

Type a): Systems with a separate electro-hydraulic controller for each steam valve, each having fault monitoring provision and possibly internal redundancy. This arrangement will normally be used with governors of type A or type B.

Type b): Systems with a common interface for all valves of the turbine or control group.
This arrangement will normally be used with governors of types B, C, or D.

A.1.3 Overspeed protection

The requirements of 5.3 apply to mechanical and electrical overspeed protection equipment, either of which may be used with electronic governors. Electronic overspeed protection may also be used with mechanical governors or in combination with mechanical overspeed equipment.

For central power station type turbines, the electronic equipment shall be designed so that no single fault shall either cause a trip or prevent a trip. Any suitable form of redundancy may be used.

For industrial type turbines, it may be acceptable to combine the overspeed electronic equipment with the governing (control) system.

A.1.4 Control method

Electronic governors may use analogue or digital control, or a combination of the two. The use of shared-purpose equipment (i.e. equipment which is partly outside that provided by the turbine supplier) is not generally permitted.

A.1.5 Power supplies

For governors of type A, at least two independent electric power supplies shall be provided by the purchaser, so as to maintain unimpaired performance of the governor during loss of a single supply for any period.

A.2 Facilities to be provided

The governor shall include the following features:

- a) Test points for on-line checks and tests.
- b) Alarms to indicate mode of equipment failure.
- c) Simple replacement of modules (on-line for type A).
- d) Where partial-arc control is used, the facilities to change to full-arc operation, if this is necessary for any particular purpose.
- e) Such other facilities as the purchaser may specify, for example:
 - remote and/or local control;
 - interfaces with other control systems;
 - unloading and trip provision;
 - variable droop;
 - wide-range and/or narrow range control;

- different sets of valves to be controlled (initial, reheat, extraction, etc.);
- speed and/or load limiting;
- load and/or pressure control;
- direct control of valve position.

A.3 Performance characteristics

The performance characteristics of an electro-hydraulic governing system are largely determined by the mechanical and hydraulic components controlling the valve positions and by the characteristics of the valves themselves. Unless otherwise agreed, the overall characteristics given in 5.2.2 shall be taken as the specified values for systems incorporating electronic governors.

The speeder device (load reference) shall be capable of adjusting the output in steps not exceeding 0,5 % of rated output.

Values given for guidance of non-linearity and stability are given in table A.1..

Table A.1 - Non-linearity and stability

Turbine MCR	MW	Up to 20	20 to 150	Over 150
Non-linearity	% of MCR	–	–	Not greater than ± 3 over range 0-100 % MCR
Stability	% of MCR			
Short-term		2,5	1,5	1
Long-term		10	10	10

A.4 Environment

The equipment shall be capable of satisfactory and continuous operation within whichever of the classes of environmental conditions in table A.2 is specified.

For all three classes, the following standard environmental conditions shall also apply:

- vibration: 10 Hz - 65 Hz, 0,15 mm amplitude
- air pressure: 68 kPa - 106 kPa

The equipment shall function correctly in the presence of radio interference of a nature and level to be specified.

The equipment shall not generate radio interference exceeding a level to be specified.

Table A.2 - Environment classes

Class	Ambient temperature range	Ambient relative humidity	Typical conditions
1	0 °C to +40 °C	45 % to 75 %	Control rooms and equipment rooms
2	-25 °C to +55 °C	45 % to 100 %	Outdoors or plant-sited
3	-10 °C to +70 °C	45 % to 100 %	Special conditions

A.5 Tests

A.5.1 Works tests

The tests to be witnessed by the purchaser shall be subject to prior agreement.

A.5.2 Site tests

Such tests shall be carried out as are necessary to set the equipment to work in all specified modes.

A.6 Documentation

The purchaser shall provide the following information in his specification:

- details of operating environment (see A.4);
- details of electrical power supplies available;
- outline of control scheme of generating unit or process;
- list of control functions required, including facilities described in A.2 as optional;
- categories of governor (A, B, C or D) and interface a) or b) which are acceptable (see A.1.2);
- special requirements for tests.

(Continued from second cover)

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 953-2 : 1990	IS 14198 (Part 2) : 1994 Rules for steam turbine thermal acceptance tests : Part 2 Method B — Wide range of accuracy for various types and sizes of turbines	Identical
ISO 2372 : 1974	IS 11724 : 1985 Basis for specifying the rules in evaluating the mechanical vibration of machines in the operation range 10 to 200 rev/s	Identical

The concerned technical committee has reviewed the provisions of following IEC/ISO standards referred to in this adopted standard and has decided that it is acceptable for use in conjunction with this standard:

IEC 1064 : 1991 Acceptance tests for steam turbine speed control system

ISO 7919-1 : 1986 Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation : Part 1 General guidelines

Only the English language text given in the International Standard has been retained while adopting it as Indian Standard, and as such the page numbers given here are not the same as in IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the results of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

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Amendments Issued Since Publication

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